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A 350-MHz BROADBAND LUMPED ELEMENT CIRCULATOR FOR TRANSISTOR PROTECTION

by

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A 350-MHz BROADBAND LUMPED ELEMENT CIRCULATOR FOR TRANSISTOR PROTECTION

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Electronic Components Laboratory

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DA Task No. 1H6-62705-A-056-01-14

U. S. ARMY ELECTRONICS COMMAND
FORT MONMOUTH, NEW JERSEY

ABSTRACT

A method of broadbanding a miniature, 'lumped element' UHF circulator using tripled-tuned networks is presented. The characteristics of such a low-loss/moderate isolation isolator package are given, vis-à-vis transistor amplifier protection applications.

CONTENTS

FIGURES

A 350-MHz BROADBAND LUMPED ELEMENT CIRCULATOR
FOR TRANSISTOR PROTECTION

INTRODUCTION

Recent reports have shown the feasibility of using miniature lumped element circulators in the VHF and UHF frequency ranges.[1,2,3]

This communication describes the broadbanded performance of a miniature UHF circulator with a passband of 300 to 400 MHz using a device manufactured by Melabs[4] - their model LB-1 "isoductor."

A recent report by McChesney and Dunn[5] described a similar device which was broadbanded to cover the 400-to 700-MHz frequency range.

The device described here was obtained as a discrete circulator, to be matched externally by using proper bandpass networks to achieve wide bandwidths and low insertion loss at lower frequencies. (See Fig. 1.)

An important application of the circulator is its use in providing protection for RF transistor amplifiers when RF power is fed directly to an antenna. Such protection is achieved when the 3-port circulator is interposed between the RF amplifier stage and antenna. Absorption of any reflective power from the antenna is provided by virtue of the matched dummy load at the third port. Transistor failure due to severe reflection or mismatch is thereby eliminated. The impedance level between the amplifier and the antenna is always maintained, thereby.

DISCUSSION

Circuit Design

According to Konishi,[1] the insertion loss of a lumped element circulator in the shunt tuned configuration - common ground point (See Fig. 1a) is given as:

$$L\ (dB) = \frac{4.96}{\eta}\left(\frac{1}{Q_c} + \frac{1}{Q_{eff}}\right) \text{-------------} \quad (1)$$

where: $$\eta = \frac{\mu_+ - \mu_-}{\mu_+ + \mu_-}\ ;\ \mu_\pm = 1 + \frac{W_m}{W_o \pm W_1} \text{--------} \quad (2,3)$$

W_m = $4\pi Ms$ (Saturation Magnetization)

W_o = γ H (internal field)

W_1 = operating center frequency of circulator

γ = gyromagnetic ratio = 2.8

Q_c = Unloaded Q of shunt capacitor

Q_{eff} = Unloaded Q of ferrite material.

It was not possible to test Konishi's equation because the circulator parameters Q_{eff} and $\mu \pm$ could not be measured; therefore, an overall insertion loss measurement was made at 350 MHz for the narrowband (5%) case, with single shunt capacitors tuned at each port (Figure 1a).

At 350 MHz, L (dB) = 0.6 dB for a 5% passband.

Three triple-tuned bandpass filters were then constructed to cover the 300 - 400 MHz range and these exhibited an average insertion loss of 0.25 dB each, with approximately 0.02 dB ripple. These units were constructed using air trimmer capacitors and distributed (lead length) inductances (See Figure 2).

In marrying each assembly to the circulator, great care was used in minimizing stray capacitance and lead length inductances. Shielding walls were constructed around the entire circuit (See Figure 2). In addition, coaxial stubs were used as shunt inductances for least loss.

The entire circulator assembly was tuned to optimum Chebychev response using the Rohde and Schwartz Polyskop generator. Results are shown in Figure 3. An impedance plot was then made and results are shown in Fig. 4.

It can be seen that an optimum of 1.0 dB has been accomplished, coincident with a nearly flat isolation response of 13 dB over this range.

In analyzing this insertion loss (Fig. 3), it should be noted that each filter (on the input and output ports, resp.) contributes 0.25 dB to the total loss. The equation for insertion loss should therefore read:[6]

$$L\ (\mathrm{dB}) = 20 \log \frac{1}{1 - \frac{Q_{Lf}}{Q_{uf}}} \quad \left(\text{discrete circulator dissipation loss}\right)$$

$$+ 4.34 \left(\frac{Q_L}{Q_u}\right) \sum_{n=1}^{3} gk + 4.34 \left(\frac{Q_L}{Q_u}\right) \sum_{n=1}^{3} gk \quad \left[\text{Dissipation loss due to input and output filters.}\right.$$

$$L\ (\mathrm{dB}) = 20 \log \frac{1}{1 - \frac{Q_{Lf}}{Q_{uf}}} + 8.68 \left(\frac{Q_L}{Q_u}\right) \sum_{n=1}^{3} gk \text{ ------------ } (4)$$

where: Q_{Lf} = loaded Q of the discrete circulator (junction)

$= \frac{\text{center frequency}}{\text{bandwidth at 3dB}}$

Q_{uf} = unloaded Q of the ferrite material

$$Q_L = \frac{\text{center frequency}}{\text{Bandwidth(ripple)}}$$

$$Q_\mu = \text{unloaded Q}$$

each filter

gk = element value for each C or L

external to discrete circulator. This includes each external shunt capacitor immediately beyond the ferrite junction. Note that the Q_μ due to this first shunt capacitor is now included in each filter and is not expressed in the term given for insertion loss of the discrete circulator itself.

According to the results given, the total insertion loss as measured

0.6 dB	+	0.5 dB	=	1.1 dB
(circulator)		(both filters)		

jibes with the plot shown in Fig. 3. Additional losses shown in the plot are due to mismatch and can be deduced from Fig. 4.

The isolation response was a function of the impedance match, accomplished at the third port and terminated (through the triple-tuned filter) in a 50 Ω coaxial OSM type load. It was found that a 50 Ω termination at the isolated port provided a better impedance match than the termination called for in the application note.[4]

CONCLUSIONS

In conclusion, it must be noted that filter tuning, though critical, was accomplished by using miniature air trimmer capacitors having low distributed inductive components. Miniaturization may be accomplished further by using ultra-miniature ceramic trimmers and ultimately, printed circuit techniques.

Broadband width and matching was accomplished using bandpass rather than low pass networks. This was because over a band of frequencies, the ferrite junction, represented by parallel L and R could be incorporated more easily into the bandpass matching network. In using the low pass structure, an admittance transformation must be made, causing possible frequency dependence.

It should be noted that broadband display was accomplished at the expense of achieving lower isolation than is normally expected at microwave frequencies ($\angle$ 20 dB).

Limited data is available indicating that the device described above is useful in providing protection for RF transistor power amplifiers.

Future work using broadband ferrite devices will concentrate on demonstrating quantitative limits of protection afforded typical RF transistor power amplifiers under worst case conditions.

ACKNOWLEDGEMENTS

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REFERENCES

1. Y. Konishi, "Lumped Element Y Circulator," IEEE Trans. on Microwave Theory and Techniques, Vol. MTT 13, pp. 852-864, November 1965.

2. V. E. Dunn, "Ultra Compact Microwave Devices," Interim Technical Report No. 2, Army Contract DAAB07-67-C-0042, October 1967.

3. V. E. Dunn and R. W. Roberts, "New Design Techniques for Miniature VHF Circulators," G-MTT Symposium, Clearwater, Florida, 1965.

4. Melabs Application Note 7 - 182, Melabs, Palo Alto, California.

5. G. McChesney and V. Dunn, "Broadband Lumped Element UHF Circulator," IEEE Transactions on Microwave Theory and Techniques, Vol. MTT 15, pp. 198-199, March 1967.

6. S. B. Cohn, "Direct Coupled Resonator Filters," Proc. IRE, Vol. 45, pp. 187-196, February 1957.

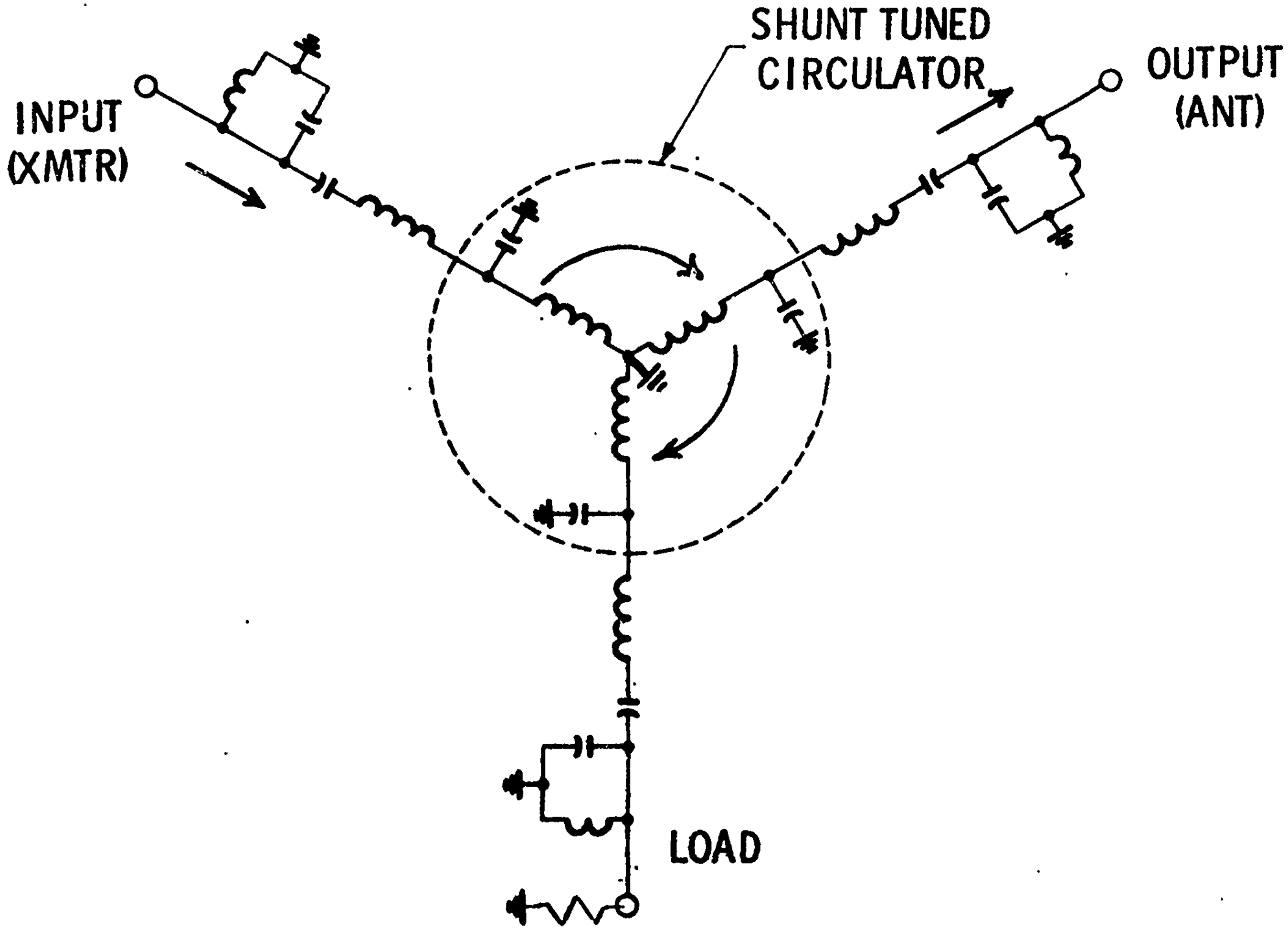

FIGURE I

SCHEMATIC OF TRIPLE-TUNED CIRCULATOR

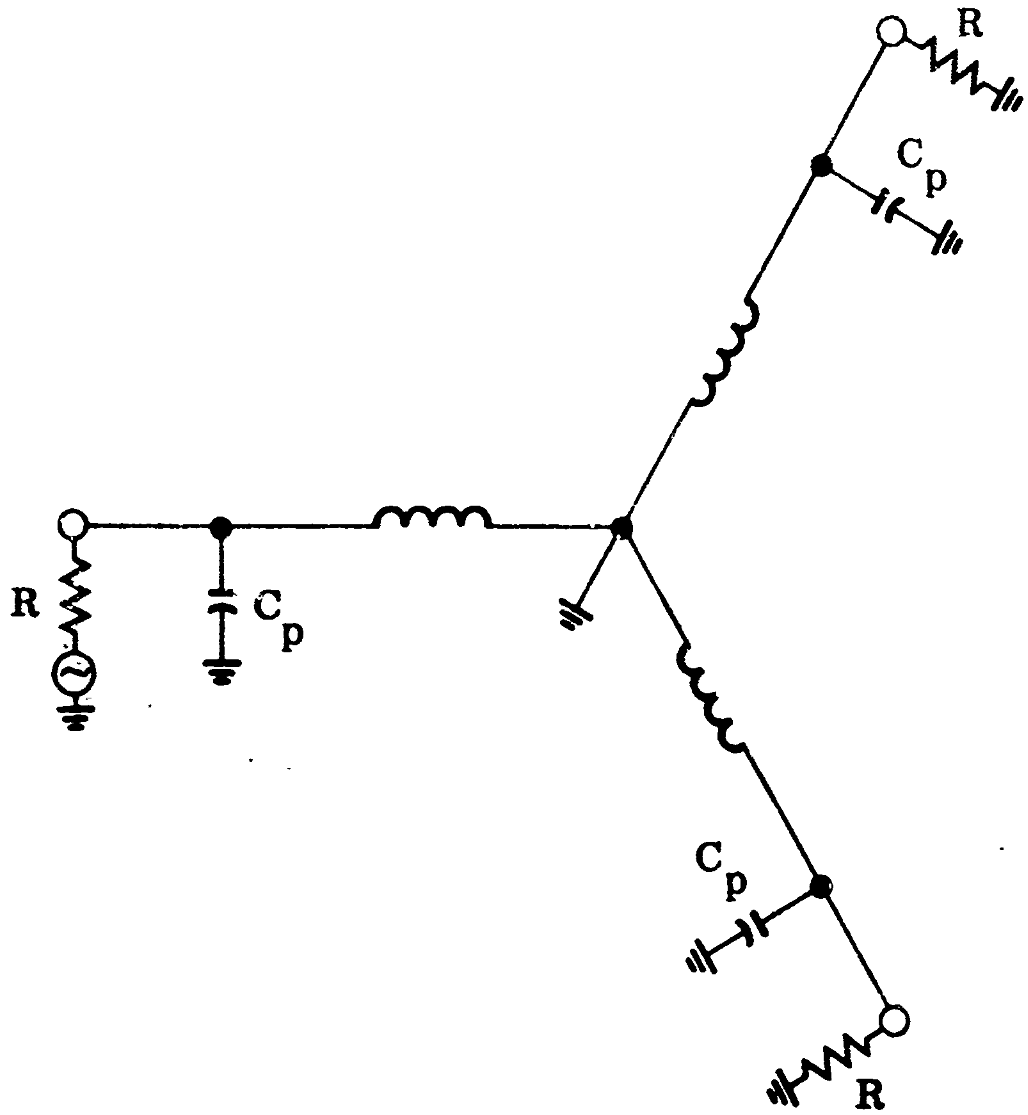

FIG. 1A BASIC SHUNT-TUNED CIRCULATOR

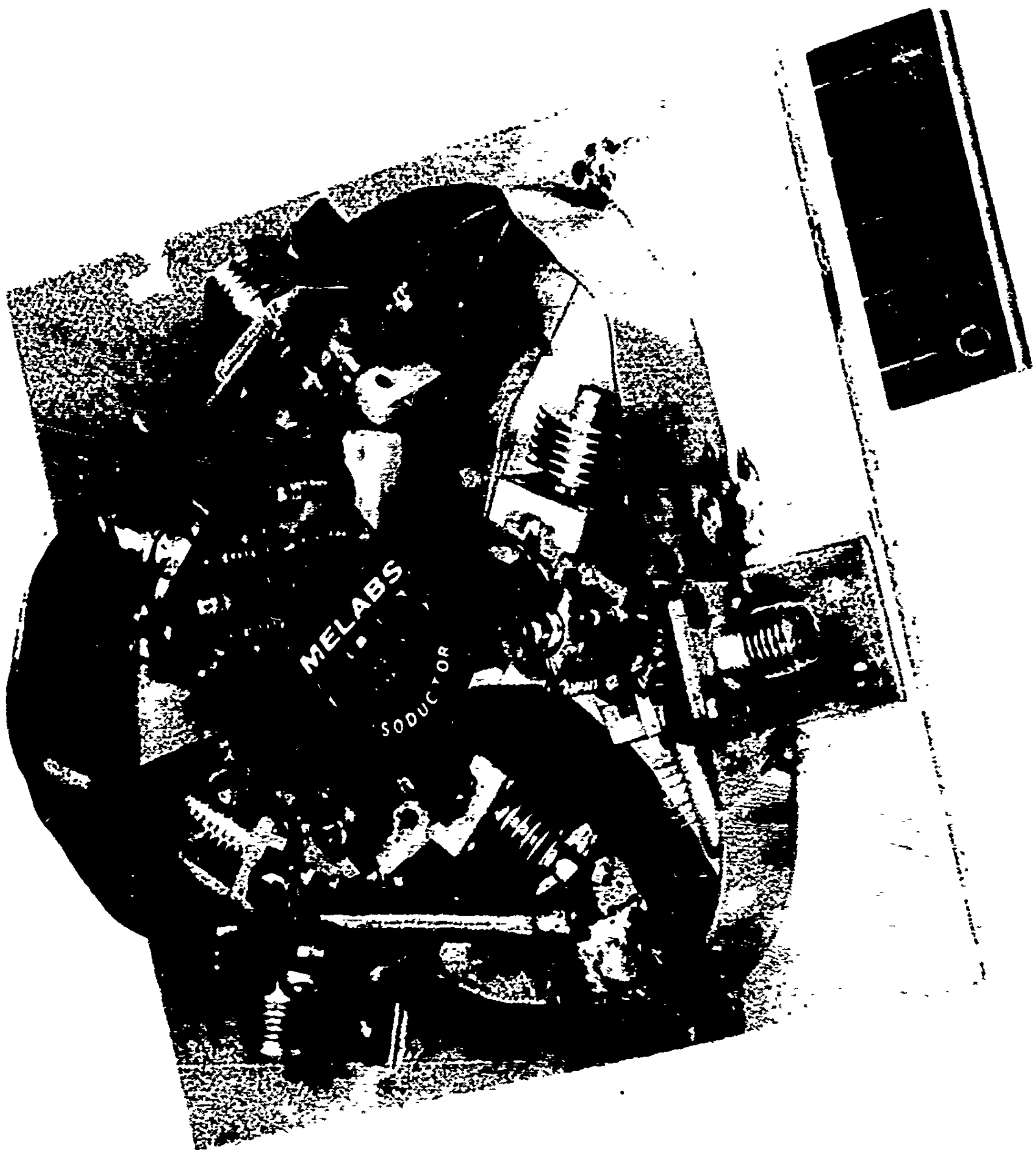

FIG. 2 300-400-MHz BROADBAND CIRCULATOR ASSEMBLY

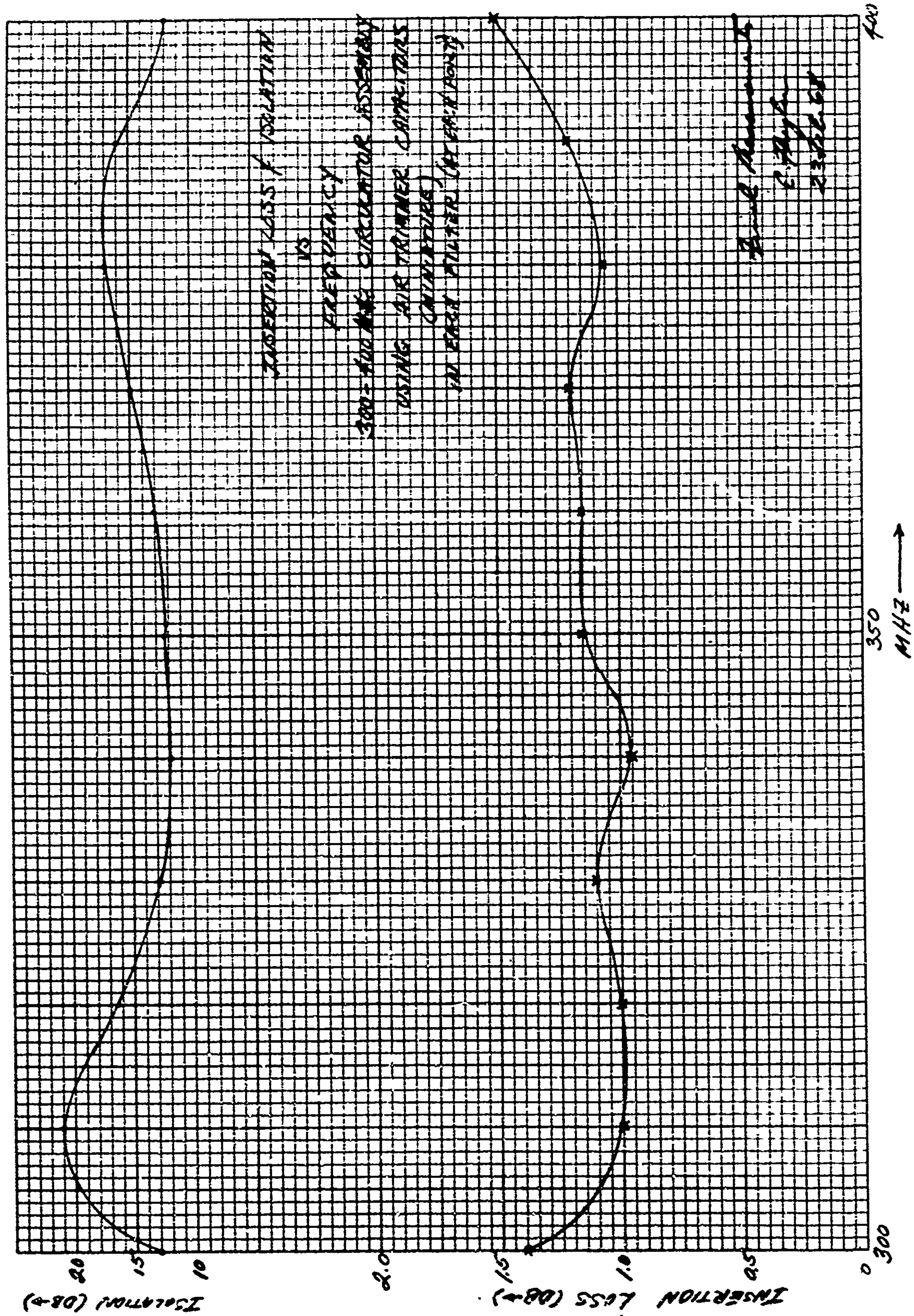

Fig. 3 Insertion Loss and Isolation Characteristics

NAME Impedance plot | TITLE BROADBAND L-C CIRCULATOR—300-400MHz

IMPEDANCE OR ADMITTANCE COORDINATES

Notes: 1. Device set up with coax stubs.
2. Shielding between ports and externally.
3. Air trimmer capacitors used.

4 March, '68

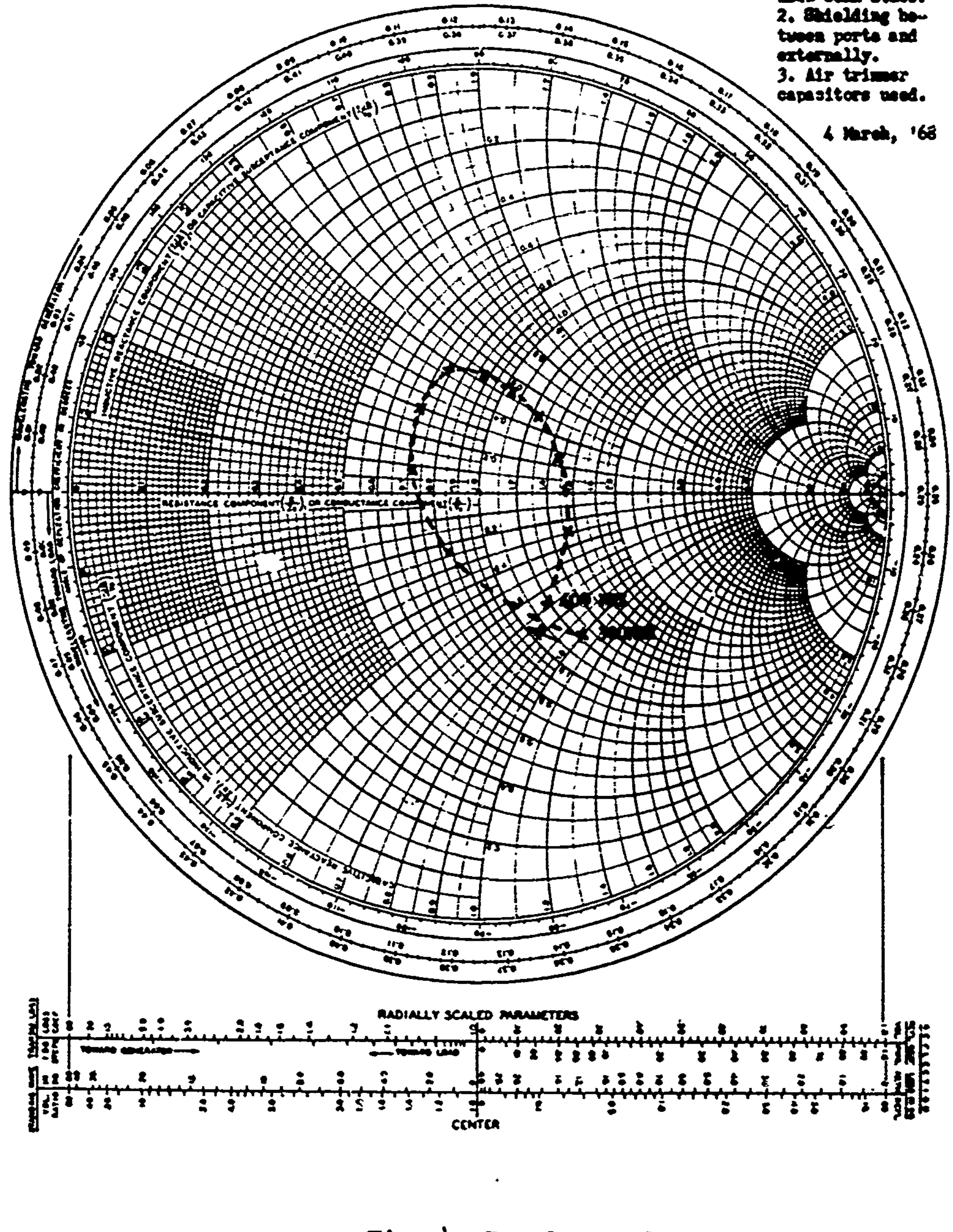

Fig. 4 Impedance Plot

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